A framework for a decision support system for cooperation in make-to-order production

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Abstract This paper proposes a method which assists the firms for cooperating in make-to-order production. More precisely, the operational decision levels of manufacturing companies are considered: the forecast scheduling and the real-time scheduling. The method organizes a production process which is distributed over several companies, by tightening the production flow with the aim of decreasing production costs. In the selected approach, the global organization is achieved progressively by a set of cooperations between pairs of actors of the companies network. We study in particular customer/supplier relationship for which the cooperation process concerns the attributes of the orders transmitted by the customer to the supplier. We assume that the relation is governed by a contract of cooperation which defines a common framework for this cooperation. Our objectives is to give a more contractual framework to the cooperation between the decision-makers, and to design support tools that assist them during the cooperation process.

1 INTRODUCTION

More and more often, the diversification of their production or the specialization of their trade induce the companies to collaborate with numerous partners, in the context of a network commonly called supply chains. New communication and information technologies increase the quality and the frequency of the data exchanges and allow to ensure the coherence of information which are shared between different actors. Nevertheless, they do not solve the coherence problem between the local decisions of each partners and the global organization of the supply chain. Thus, each actor is free to change at any moment a collective decision, inducing a global organisational instability.

To counteract this problem, the decisional autonomy of each actor needs to be specified in order to achieve a global stability of the collective decisions. This decisional autonomy can be specified if the actors adopt a cooperation process in which a local decision, if it affects the organization of external companies, would be first negotiated. The aim of this negotiation is then to increase the life duration of the decision. In the same way, the change of a local decision having collective impacts induces the author of this decision to renegotiate with his partners in order to achieve a trade-off which satisfies the community. The benefits of the cooperation are also shared by every actors of the community [7]. In the following, we refer to the set of partners involved in the cooperation process by the name community of interests.

In a production system, cooperation processes can have a lot of advantages. First, they contribute to a better tension of production flows, to a better adaptation of the working capacities, and to a better stability of the organization of the community of interests. So, it induces
a global reduction of the production costs. On the other hand, the cooperation processes allow a collective management of the risk since an actor can be helped by the community to try to absorb the disturbances which disorganize him. A second goal of the cooperation is thus to allow a better risk management.

First, this paper recalls the context and the problematics related to the cooperation between companies. Then it describes a framework to the cooperation in the suppliers-customers relationship and it gives a cooperation tool support we would like to develop.

2 CONTEXT

2.1 STATE OF THE ART

Many research activities show that problems related to the cooperation are not obvious. In particular, we distinguish the program PROSPER of CNRS which allowed research teams from different disciplines (sciences for the engineer, human and social sciences) to work together in order to increase the efficiency of the production systems in a context of cooperation between companies [9]. We are inspired by works of [11] which deal with the relationship between cooperation and design.

Many approaches deal with cooperation. First, we can distinguish the works dealing with the cooperation at the tactical levels (planning) and suggesting macroscopic models which secure a global coherence of the planning and the allocation of workload [3]. Then, some works propose a global multi-site production planning coupled with local schedulings [5]. Our paper is denoted to the cooperation at operational levels (forecast scheduling and real-time scheduling) in a point-to-point mode between two companies belonging to a same community of interests in a make-to-order production context, each of them having a local scheduling module. In particular, we are interested in customer/supplier relationships which can be compared to [10] dealing with customer/subcontractor relationship. Moreover, as [1] which introduces the concept of “order contract” in a relationship between customers and their subcontractors in the context of cyclic production, we suppose that each pair of company of a same community of interests contracts their cooperation.

2.2 FUNCTIONS OF THE COOPERATION

The cooperation can be defined as a collective action organized amongst a set of actors sharing a set of joint interests. Although this general definition is relatively consensual, the approaches of the cooperation are different when the functional description of the cooperation is considered. We chose to adopt the logic of the works proposed in [4][6] and in the chapter 9 of the book [11]. These works distinguish mainly three cooperation functions: to negotiate, to coordinate and to renegotiate. In a make-to-order production context, we suppose that a process of negotiation has to start when partners of a same community of interests would like to organize the production of an order. The aim of this negotiation is to find a collective decision (the manufacturing order characteristics) that satisfies the concerned partners. When this decision has been taken, the actors have to coordinate themselves in a common temporal framework in order to synchronize their activities needed to produce this order. Thereafter, if an inconsistency, connected to the order, is detected by a partner, then a process of renegotiation has to be initiated. The renegotiation and the negotiation have the same goal (to find a
collective decision), but a renegotiation always refers to a previous collective decision.

2.3 OBJECTS OF THE COOPERATION AND MODES OF COMMUNICATION

We suppose that information exchange during negotiation, coordination, and renegotiation always concerns quantities, deadlines or costs of orders. Moreover, whatever the considered function is, the cooperation induces a frequent communication between actors. This communication is synchronous when actors cooperate simultaneously in a virtual or a real shared space, and asynchronous when actors cooperate without simultaneity. We chose to use an asynchronous communication mode which seems both easier to realize and better adapted to a make-to-order production context. Finally, we consider that cooperation is implemented by a set of point-to-point communications corresponding to different exchanges between couples of supplier-customer.

2.4 A MULTILEVEL COOPERATIVE APPROACH

As we already mentioned, actors who would like to cooperate form a community of interest. In order to avoid an organizational instability in this community of interest, the autonomy of each actor must be defined. We suppose that this autonomy is defined by a set of cooperation contracts between each couple supplier-customer of the community. We detail this contract notion in the subsection 3.4. Our goal is to design cooperation tools which realize a coordination and a decision-aid for partners in order to build a trade-off between local objectives of each actor and global objectives of the community of interests which satisfies cooperation contracts. In a make-to-order production context, these tools are connected to the three classical functions of a production management structure (cf. figure 1).

Moreover, even if planning, scheduling and real-time scheduling have the same basic problems, we consider that tools are specific for each level because the production “granularity” is different at each level. So our works are relatively similar to works in [6] and [8] which respectively propose a cooperation aided decision system for the scheduling level and for the planning level.
In order to realize these tools in a generic way, we suppose that management production data from a given decision level are aggregated in the cooperation module which corresponds to the same level. We can notice that the farther from short-term the considered level is, the more important the aggregation is. Indeed it is not useful to handle data in the cooperation process with the same detail level than in the production management functions because our aim is to provide decision-aid elements for cooperation but not to organize a manufacturing process globally. We also suppose that a common communication language supporting cooperation between actors is defined and that cooperation tools work in a point-to-point mode.

3 A COOPERATION SCHEME FOR CUSTOMER-SUPPLIER RELATIONSHIPS

3.1 PROBLEM STATEMENT

As already mentioned, the result of a negotiation process is a manufacturing order. The figure 2 gives an example of a manufacturing order for which 650 products must be gradually supplied for February 28th. This figure also represents the cumulative production curve of the supplier reserved for a customer and the cumulative needs curve of this same customer. Ideally the cumulative production curve must be equal to the cumulative needs curve or, failing that, it must be above the cumulative needs curve. But, if nothing is specified between the two partners, the customer can have more important needs than realized products. This case is presented on the figure 2 when, for instance the customer needs 250 products for the February 10th and the supplier forecasts to realize 200 products at this same date.

![Cumulative needs curve of client](Cumulative production curve of supplier)

Figure 2: Production and needs curves for a same manufacturing order

So the negotiation process must induce customers and suppliers to consult each other in order to improve the consistency between the production and the real needs. In this aim, we introduce the concept of decision framework.

3.2 DECISION FRAMEWORK

In make-to-order production, we assume that the decision framework, which is the result of a negotiation process, represents a supplier engagement to put a variable quantity of products at
his customer’s disposal in one or more temporal windows. Let us emphasise that the decision framework also commits the customer to remove products which are placed at his disposal. So a decision framework can be compared with a set of constraints related to the output stock levels of the supplier in some temporal intervals, or conversely, with a set of constraints related to the input stock levels of the customer. This approach can be compared to [2] and [12] which describe a quantity flexibility contract used for instance in electronic industry. But, in this context, only the customer has a quantity flexibility and the supplier is obliged to provide his customer with the order quantity.

![Cumulative needs curve of client](image1.png) ![Cumulative production curve of supplier](image2.png)

Figure 3: A decision framework

Figure 3 gives an example of a decision framework corresponding to an order of 650 products to complete for February 28th. We suppose that the decision framework divides up the order in four batches: the supplier must put between 50 and 250 products at customer’s disposal between February 01st and February 04th, then he must have produced between 200 and 525 products of the order between February 10th and February 12th, then between 400 and 650 products of the order between February 23rd and February 24th, and finally 650 products for February 28th.

We can notice that each rectangle surface and the rectangle position have influence on the available flexibility of the supplier in order to organize his production. Indeed the more important the rectangle surface is (or, if surfaces are equal, the farer from the time origin the rectangle position is), the more the supplier will easily find a production which satisfies the decision framework. Moreover the flexibility notion and the risk notion can be connected with this approach. Indeed, the greater the supplier flexibility is (important rectangle surface), the less he risks not to satisfy the decision framework but the more customer stocking needs risk not to be respected. Conversely the smaller the rectangle surfaces are, the harder the supplier production management is but the more the customer needs would be respected. The aim of the negotiation is to size a decision framework in order to reach a trade-off which satisfies both supplier objectives and customer objectives. So a decision framework must satisfy two points of view. We will detail this point in subsection 4.2.
3.3 BASIC PRINCIPLES

A negotiation process is initiated when one of the partners makes an order proposal to another one. An order proposal specifies an initial decision framework which will become more and more precise as negotiation progresses. A proposal can be issued from a customer who would like to place an order, or it can be issued from a supplier who would like to propose, for instance, a commercial offer to one of his customers. Figure 4 illustrates a case when a supplier receives an order proposal from the customer Despontin which concerns a product A. This customer would like that between 6 and 11 units of product A will be available between July 15th at 6 p.m. and July 16th at 6 p.m.. The partner, who receives this order proposal, can refuse it or accept it, he can also generate a counterproposal. Generally, a conversation corresponds to a sequence of proposals and counterproposals, which ends either by an acceptance or by a refusal.

![Figure 4: Representation of conversations related to negotiation processes](image)

We distinguish proposals of two distinct types. Indeed, if it is accepted, a proposal can induce either a definitive engagement of the supplier, or no engagement at all if the response only concerns the order feasibility. The first case is referred to a proposal for engagement for which the negotiation process ends either on an engagement (acceptance) or on a refusal. The second case is referred to a proposal for valuation for which the negotiation process ends either on a feasibility result (acceptance) or on an unfeasibility result (refusal). In this case, if a conversation concludes with the feasibility of a proposal, no partner is committed since a proposal for engagement is anyway needed in order to realize a firm engagement between the two partners. Moreover this proposal for engagement will not necessarily give the same decision framework that the one which was determined in the feasibility analysis.

The coordination process consists in information message sharing. These informations can concern deadlines, quantities or prices. In the example presented in figure 5, the supplier informs his customer Despontin that the order would be delivered normally the 16th July at 12 a.m.. The decision-maker can handle the generated messages. Indeed, he can decide either to send them, or to differ them, or to delete them, or to modify them before sending.

A renegotiation process is initiated when one of two partners would like to modify a de-
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Figure 5: Illustration of the coordination

Figure 6: Illustration of the renegotiation

decision framework. For instance, a supplier can ask for a modification when his production cannot respect the decision framework, or a customer can ask for a modification when supplies are not consistent with his needs (cf 3.2). Figure 6 illustrates a renegotiation request from the customer Despontin concerning his order Commande_1. In order to initiate a renegotiation, the decision maker sends a proposal. For instance, in figure 6, the customer would increase the minimal quantity of the order to be equal to 7 products instead of 6 (cf figure 4). The partner receiving this renegotiation request, can accept or refuse it or can send a counterproposal.
3.4 **CONTRACT OF COOPERATION**

In order to help a supplier-customer couple to specify a manufacturing order, we suppose that they have agreed a cooperation contract. This contract allows to avoid an organizational instability by specifying the autonomy of each actor. The clauses of this contract specify constraints that the coordination, negotiation and renegotiation processes have to satisfy. These constraints define a framework for each of these functions which is different according to the considered temporal framework (cf. figure 7). Indeed, as we will see in the following, the negotiation, the coordination or the renegotiation processes do not have the same constraints if they are considered at short-term or real-time levels.

![Temporal Framework](image)

**Figure 7: Frameworks of cooperation contract**

We suppose that the definition of the cooperation contract is a strategic task which is realized by each pair of actors when a community of interests is created. For this reason, the contract duration life is supposed to be longer than the cooperation process duration life. However a contract can be modified in order to take production context variations into account.

The negotiation framework formulates a set of constraints which any negotiation process must satisfy. Especially, for each order, it specifies minimal and maximal quantities that a process initiator can require according to the temporal framework which it depends on. It also specifies minimal and maximal deadlines according to ordered quantities, and minimal and maximal product prices according to ordered quantities and deadlines. Finally it can eventually specify minimal number or maximal number of batches for each order.

For instance, the cooperation contract illustrated in figure 8 concerns a supplier and his customer *Briand*. The negotiation framework of this contract specifies that each order must contain between 5 and 10 products for a deadline varying between 7 and 10 days and for a price varying between 10 and 15 euro per unit. The coordination also needs a framework. This framework integrates a communication protocol which defines how partners must communicate. This communication can be synchronous (reunion, video-meeting, etc...) or asynchronous (fax, mail, etc...). This protocol defines also exchange rules. For example, when an actor sends a message in order to start a communication, a rule can impose that an acknowledgement is returned in order to notify him that his request has been taken into account.

The coordination framework also defines the cooperation objects which have to be exchanged and the time of the exchanges. In our case, coordination essentially concerns quantities, deadlines and costs which are exchanged either at periodic times (every week, every morning, etc...) or at “key” times (as soon as 90% of the quantity is produced, as soon as dead-
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4.1 A SUPPORT FOR NEGOTIATION

For helping the decision-makers to elaborate proposals and counterproposals, the cooperation tools must offer a decision-aid in order to achieve a trade-off which satisfies the two concerned parts. As the result of a negotiation process is a flexible decision framework corresponding to a negotiated new order, the aim of a decision-aid for negotiation is to underline the influence of this new order on the already existing orders. Indeed, the position, width and

lines are 10% late, etc...). For the example in figure 8, the coordination framework between two actors specifies that every 48 hours the supplier has to send an information concerning the quantity which he plans to supply to his customer. The supplier must also communicate this quantity as soon as it is more than 2% different of the last communicated quantity. The coordination concerns also deadlines which are communicated every 24 hours or as soon as a deadline is more than 5% different of the last coordination deadline. Finally, coordination deals with prices which are communicated every 24 hours or as soon as the unit price is more than 1% different from the last communicated price.

When a decision framework cannot be satisfied any more, a renegotiation process has to be initiated in order to build up a new consistent framework. This process is also constrained by the renegotiation framework. These constraints concern the quantity variation, the deadline variation and the price variation which are admitted between the initial decision framework and the new framework. For example in figure 8, the contract specifies that quantities, deadlines and prices cannot vary more than respectively 5%, 10%, 15% from the initial decision framework.
length of the new decision framework have an influence on the satisfaction of the already existing frameworks.

For instance, we consider the already existing decision frameworks of Figures 9 and 10. Figures 13 and 15 show the insertion impact of a new decision framework from a new customer presented on Figure 11. The blackened zones of decision framework Commande\textsuperscript{Despontin,1} and Commande\textsuperscript{Briand,1} represent the decision space which becomes impossible to reach after the new framework insertion. Here, only a part of the decision framework of Commande\textsuperscript{Despontin,1} would be feasible and the decision framework of Commande\textsuperscript{Briand,1} would not be satisfied any more.

The decision-maker can then accept this new decision framework, or can modify its position or its size in order to elaborate a counterproposal. If he accepts it, he will not be able to satisfy his agreement made with his customer Briand and it would be suitable to start a renegotiation process for the order Commande Briand\textsuperscript{1}. On the other hand, if he modifies the new framework from Figure 11 to Figure 12, he would be able to measure the impact of this change on the other decision frameworks (cf. Figures 14 and 16). When a satisfying position and size have been found for the new decision framework, a counterproposal is sent to the other partner who can then elaborate a new proposal. This process is repeated as long as a trade-off satisfying the couple of partners is not found, or it is stopped when one of the two partners decide to interrupt the negotiation process (refusal).

4.2 A SUPPORT FOR COORDINATION

The objective of the workshop supervision is to allow decision-makers to see the forecast state of an order in order to incite them to react by renegotiating a decision framework when it is obvious it will become inachievable. We suppose that informations concerning products in progress or necessary supplying to each order, are regularly exchanged between the supplier and the customer related. As illustrated in Figure 5, these messages can be automatically generated by using rules of the coordination framework. So, from this point of view, a supplier interface would display the cumulative production curve and a customer interface would display the cumulative needs curve. Moreover, if the coordination framework allows it, a supplier can have access to the totality or a part of data related to his customer needs, and conversely a customer can have access to data related to his supplier production.

For example, data in Figure 17 allow a supplier to watch at the same time his production (curve) and his customer supplying needs (rectangles). Figure 18 represents data which allow a customer to observe his supplying needs (curve) and the availability dates of products that the supplier has planned to provide. In this example, the decision framework is satisfied from the supplier and the customer point of views. However, according to Figure 17, the customer would be encouraged to renegotiate the 3rd rectangle of this framework because the availability date of his supplying is too late compared to his real need, even if it satisfies the decision framework he has accepted.

4.3 A SUPPORT FOR RENEGOTIATION

The goal of a renegotiation-aid is to allow partners to build up a coherent collective decision with respect of the cooperation contract.

Figure 19 illustrates a case when a customer needs a minimal number of 7 products instead.
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Figure 9: Existing decision frameworks for customer Despontin

Figure 10: Existing decision frameworks for customer Briand

Figure 11: The new decision framework

Figure 12: Changes of new decision framework

Figure 13: Satisfaction of decision framework of customer Despontin

Figure 14: Satisfaction of decision framework of customer Despontin

Figure 15: Violation of decision framework of customer Briand

Figure 16: Satisfaction of decision framework of customer Briand
of 6 (cf figure 6). The supplier has anticipated to let 8 products at his customer’s disposal. So, in this example, the supplier delivers always a product quantity which remains coherent with the new decision framework, even after the modification required by the customer then the supplier can accept this proposal without any adjustment of his production. However, this decision framework modification can impact other decision frameworks. Therefore, the cooperation tools must highlight the consequences on the other frameworks, and the supplier will be able to accept, refuse or make a counterproposal.

Figure 19 illustrates a more tricky case when a supplier is no more coherent with the decision framework due to some difficulties. Thus, only 6 products can be placed at his customer’s disposal instead of 7 with regard to the decision framework. In this case, the supplier should be the cooperation process initiator. The cooperation tools must help the supplier to formulate a proposal which minimizes the consequences on his previous organization. For instance, the decision framework can be shifted (figure 21) or it can be split up (figure 22) in order to become coherent again with the production. Then, the customer has also the choice to accept, to refuse or to make a counterproposal to the renegotiation proposal sent by the supplier.

5 CONCLUSION

In this paper, we consider that a cooperation process is made of 3 functions (negotiating, coordinating, renegotiating) which are submitted to constraints. Each pair of actors, which decides to form a community of interests, signs a cooperation contract which specifies these
constraints. These constraints are characteristics of each function and depend on the temporal framework in which the cooperation process takes place.

First we defined problems related to the cooperation process. Then, with an example, we showed a scheme for a decision-aid which cooperation tools would be able to propose. The first objective is to help partners to determine order parameters (quantities, deadlines, prices). Then these parameters define a decision framework which incorporates flexibility. We showed also how actors are suggested to define together their decisional autonomy when a decision framework is created.

After the decision framework specification, the partners coordinate themselves by satisfying constraints which are formulated in a coordination framework. Tools, which support this cooperation phase, must be designed in order to manage the semiautomatic coordination in a community of interests. Thanks to this semiautomatic coordination, informations that partners need, flow in due time.

Finally, when a decision framework is no more valid, cooperation tools must help the decision-makers to renegotiate. For that, they must achieve a trade-off between local objectives of each actor and global objectives with regard to the initial decision framework. This renegotiation is also submitted to constraints which are formalized in the renegotiation framework.

Now our aim is to determine an aggregate model which allows to design decision-aid tools for the negotiation and renegotiation phases of the proposed cooperation process. This model will have to be robust compared with detailed constraints considered in the scheduling function of each company in order to have coherent decisions between those taken in the cooperation stage and those taken in production management. An other problem concerns choice of a communication language which can support the different particularities of a cooperation process. These aspects have been developed in particular in previous works realized by Jean-Pierre Camalot [4] and we intend to use them.

References


